

Are the Paleozoic Plays the Future of Unconventional Gas in Romania?

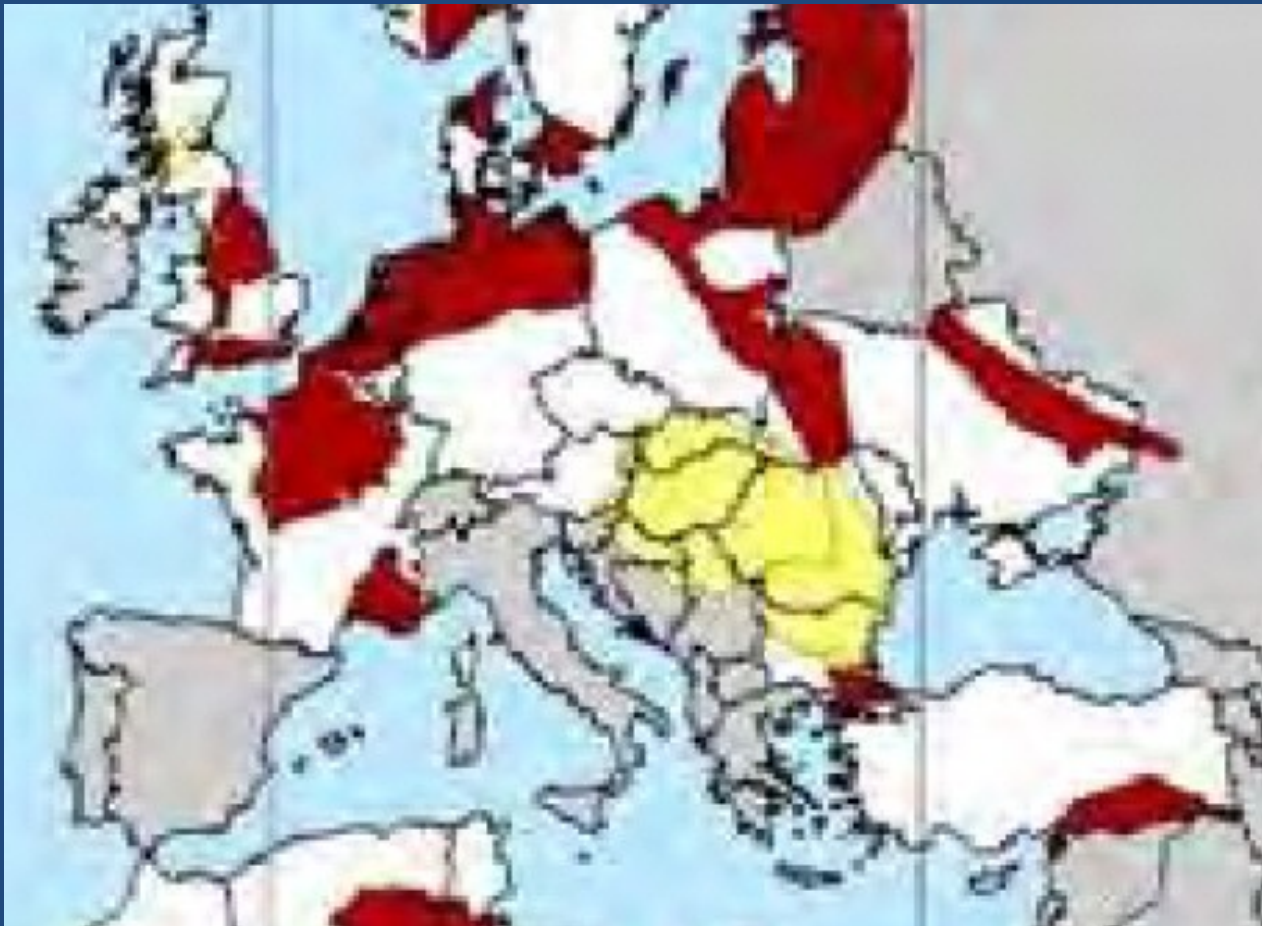
An Attempt of Assessing the Resource

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Map of major Shale Basins in Europe
(from U. S. Energy Information
Administration *World Shale Gas
Resources: An Initial Assessment of 14
Regions Outside the United States, 2011*)

Legend

- Assessed Basins with Resource Estimate
- Assessed Basins without Resource Estimate
- Countries within Scope of Report
- Countries outside Scope of Report

22°E

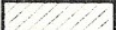
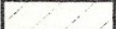
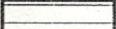
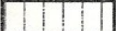
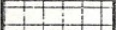
24°E

26°E

28°E

Main Tectonic Units of the Carpathian Foreland.

from Sandulescu and Visarion 1988

-  East European Platform
-  Scythian Platform
-  Miechow Depression
-  North Dobrogea orogen
-  Central Dobrogea
-  South Dobrogea
-  Basement of Valachian type
-  Danubian nappes

Moesian Platform

Assessed areas

0 100 km

48°N

MOLDOVA

46°N

46°N

MOESIA

44°N

44°N

22°E

24°E

26°E

28°E

Danube

Olt valley

Damborvia valley

Brasov

Pitesti

Bucuresti

Buzau

Focsani

Onesti

Piatra Neamt

Cimpulung

Bistria valley

Siret valley

CBF

SiF

ScF

VF

BF

TF

CF

TKE

MF

JF

CTF

IME

PCF

COF

Jiu valley

US Geological Survey recommended peer-reviewed assessment methods:

- **Volumetric** (*the assessment uses a geology-based methodology*)
- Material balance (p/z-plots)
- Analogy
- Decline curves
- History matching
- Type curves

Volumetric calculation formula applied by U. S. Energy Information Administration for *World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States, 2011*

The calculation of **free gas in-place (GIP)** uses the following standard reservoir engineering equation:

$$GIP = \frac{43,560 * A h \Phi (1 - S_w)}{B_g}$$

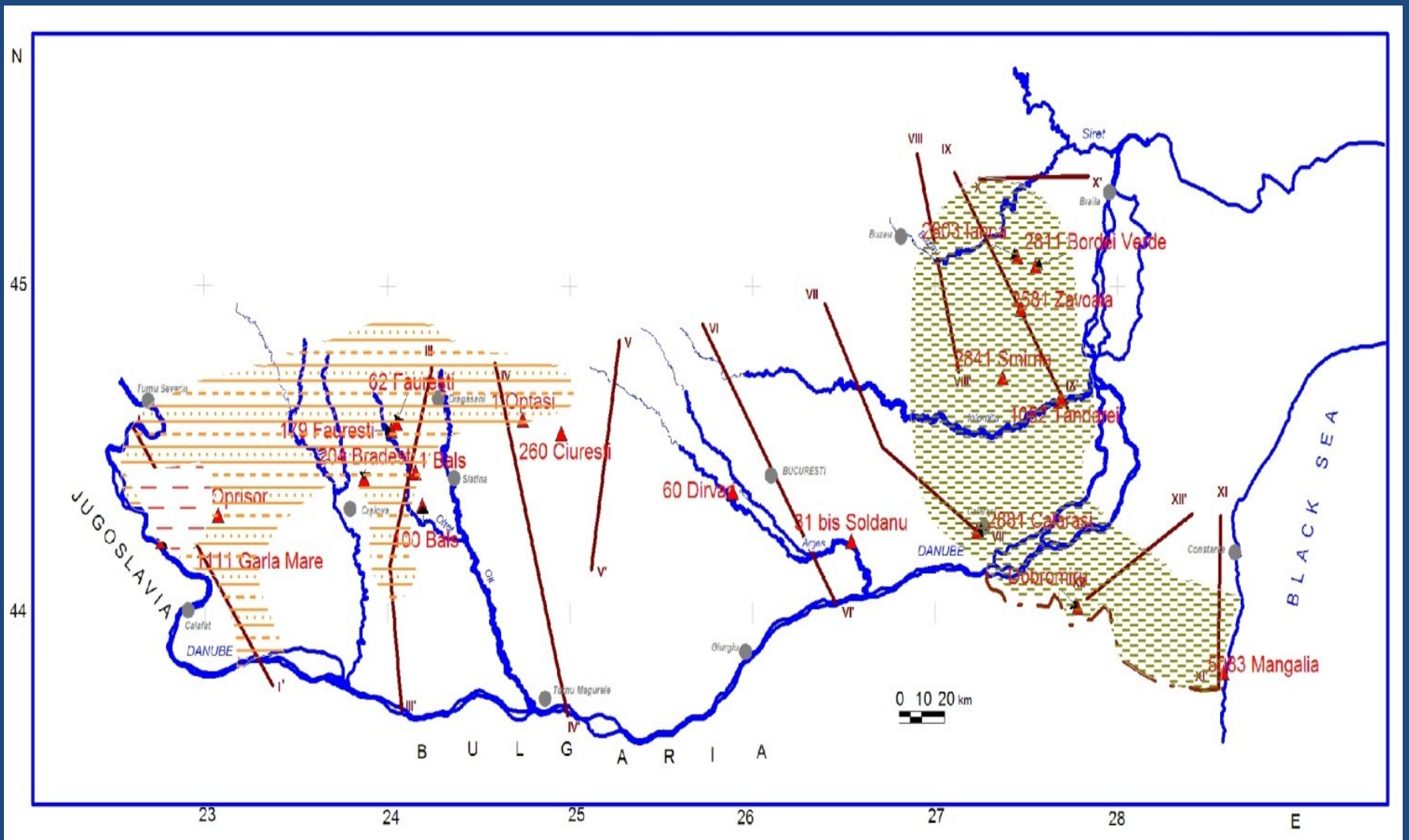
Where: $B_g = \frac{0.02829 z T}{P}$

Adsorbed gas in-place is calculated using the formula below (where P is original reservoir pressure).

$$GC = (VL * P) / (PL + P)$$

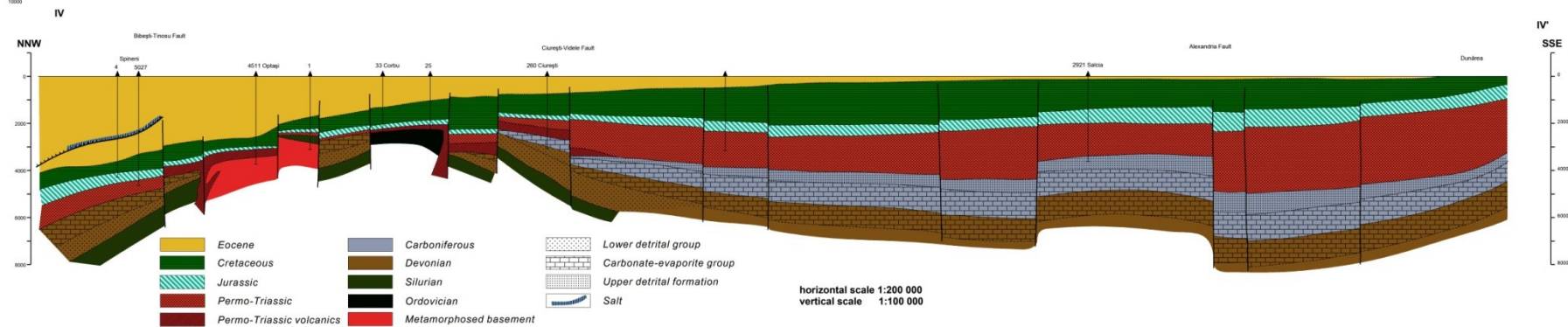
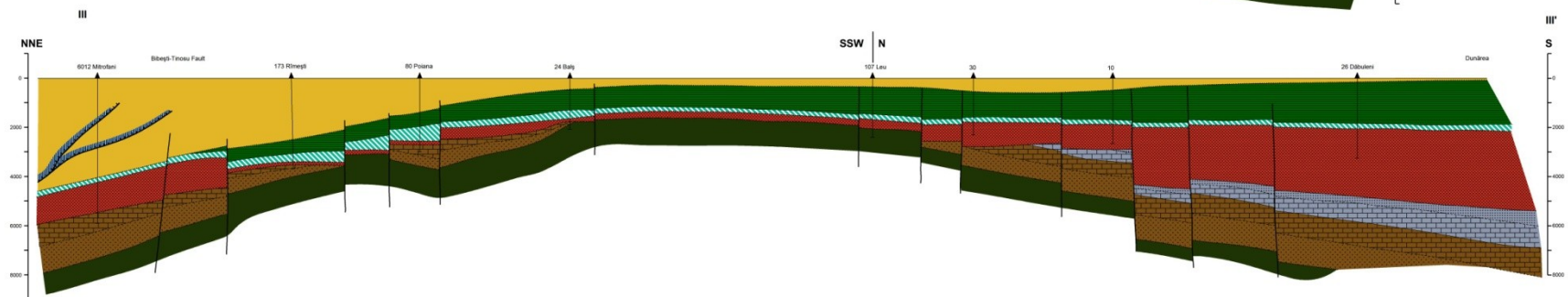
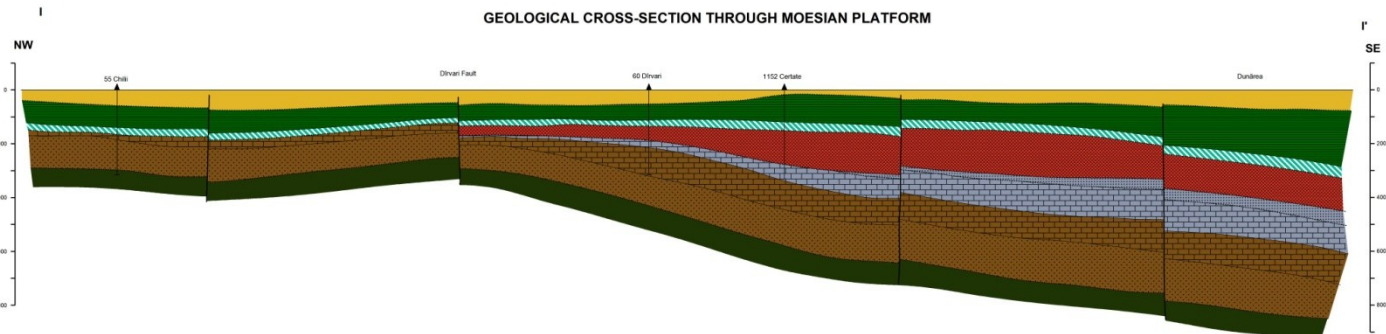
Data collected for the Geologic Analogs (GA)

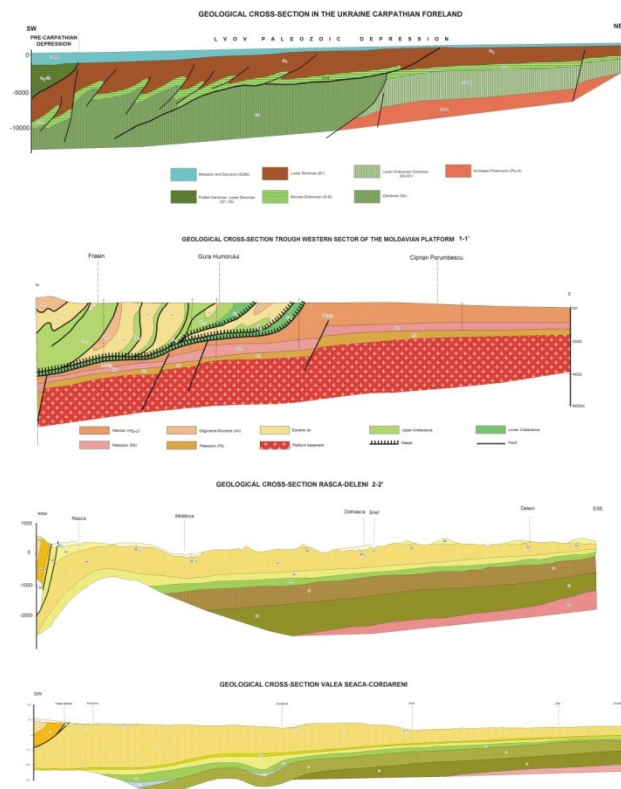
	MOESIA			MOLDOVA		
PLAYS	Lom-Bailesti Sub-Basin	Optasi Uplift (includes Alexandria margin Sub-basin)	Calarasi Sub-basin (includes S Dobrogea)	Western Limit of the Moldavian Platform	Barlad Half Graben (Scythian Pltf.)	Data Sources
Number of wells in portfolio that bottomed into the Lower Paleozoic formations	5	3	3	6	3	Iordan, 1984, 1990, 1998; Seghedi A. 2005; Paraschiv D., 1979; Beju, D., Dăneț, N., 1962; Brânzilă, M., 1999; Ionesi, L., 1994; Olaru, L., Brânzilă, M., Țabără, D.,
Number of cross sections	1	4	6	8	3	Geological Inst. Publications
TOC data from laboratory analysis	4		6			Momea et al., 2001
Thermal Maturity (Ro%) data from laboratory analysis	4		6			



Location of cross-sections and key wells that bottomed in the Lower Paleozoic formations of the Moesian Platform. Shaded areas outline the Silurian plays (after A. Seghedi, 2004)

GEOLOGICAL CROSS-SECTION THROUGH MOESIAN PLATFORM





LEGEND

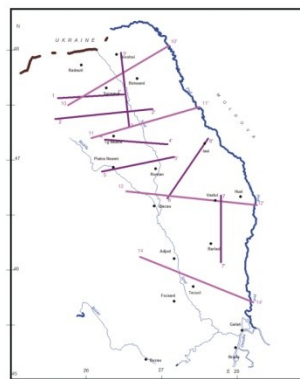
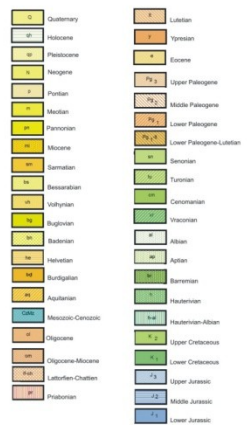
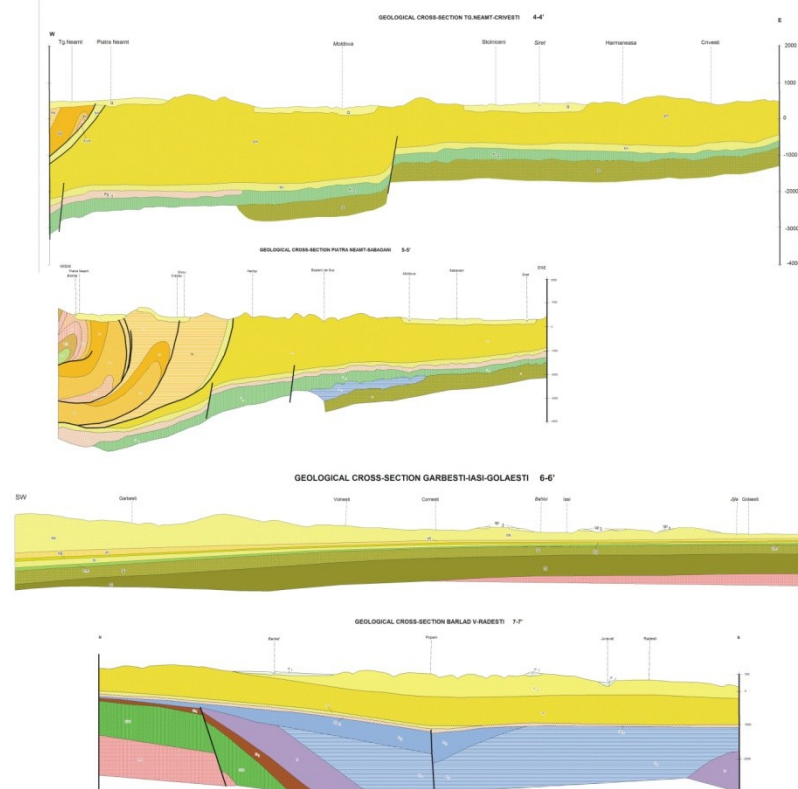


Plate 1 GEOLOGICAL CROSS-SECTIONS
THROUGH MOLDAVIAN PLATFORM (Northern sector)



LEGEND

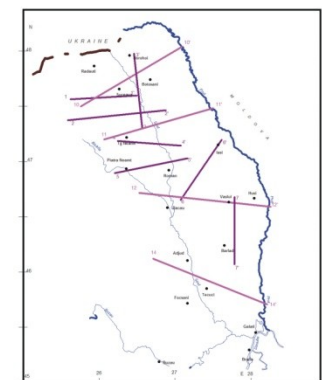
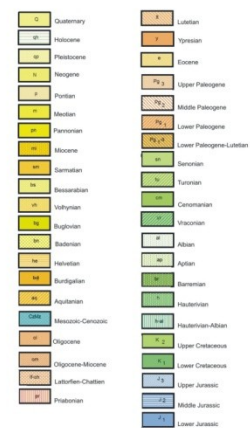
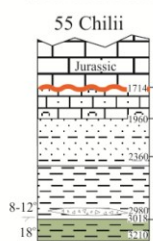
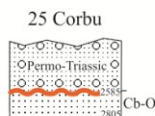
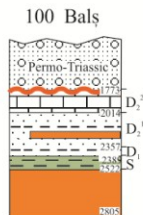
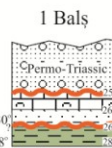
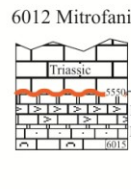
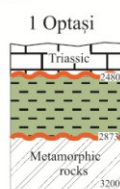
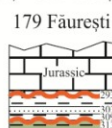


Plate 2 GEOLOGICAL CROSS-SECTIONS
THROUGH MOLDAVIAN PLATFORM (Southern sector)

STREHAIA HIGH

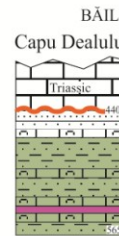
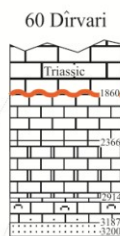
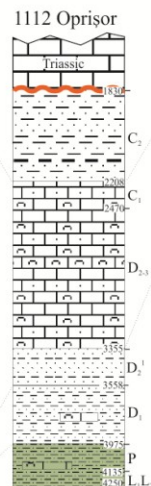
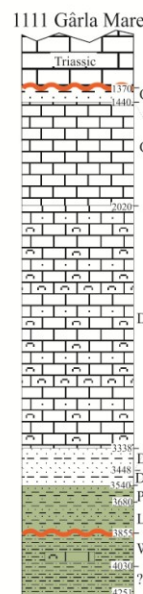


BALȘ-OPTAȘI HIGH

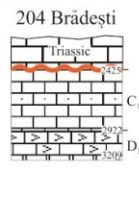
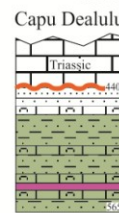


LOM DEPRESSION

WESTERN MARGIN OF BĂILEȘTI BASIN

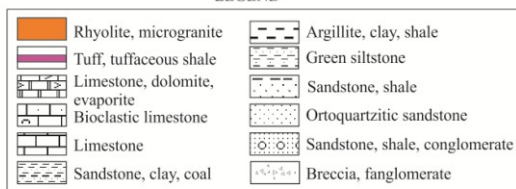


BĂILEȘTI BASIN



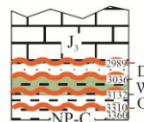
Western Moesia

LEGEND

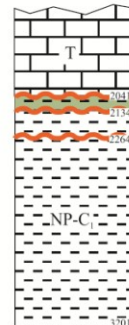


BORDEI VERDE HIGH

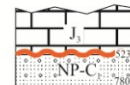
2803 Ianca-Berlescu



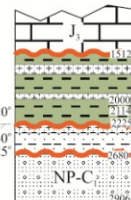
2811 Bordei Verde



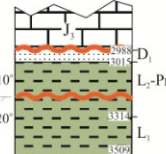
1051 Gura Ialomiței



1052 Tândărei

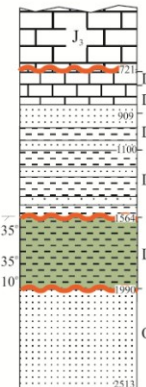


2581 Zăvoaia



SOUTH DOBROGEA

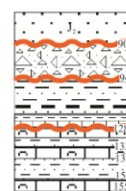
5083 Mangalia



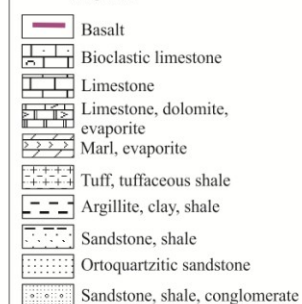
5082 Mangalia



Dobromir

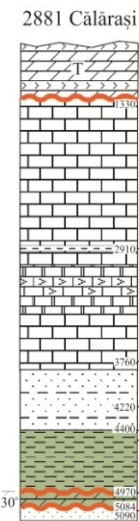
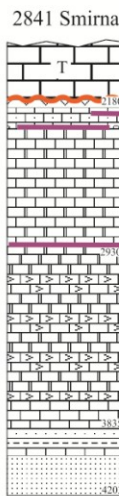


LEGEND



Eastern Moesia

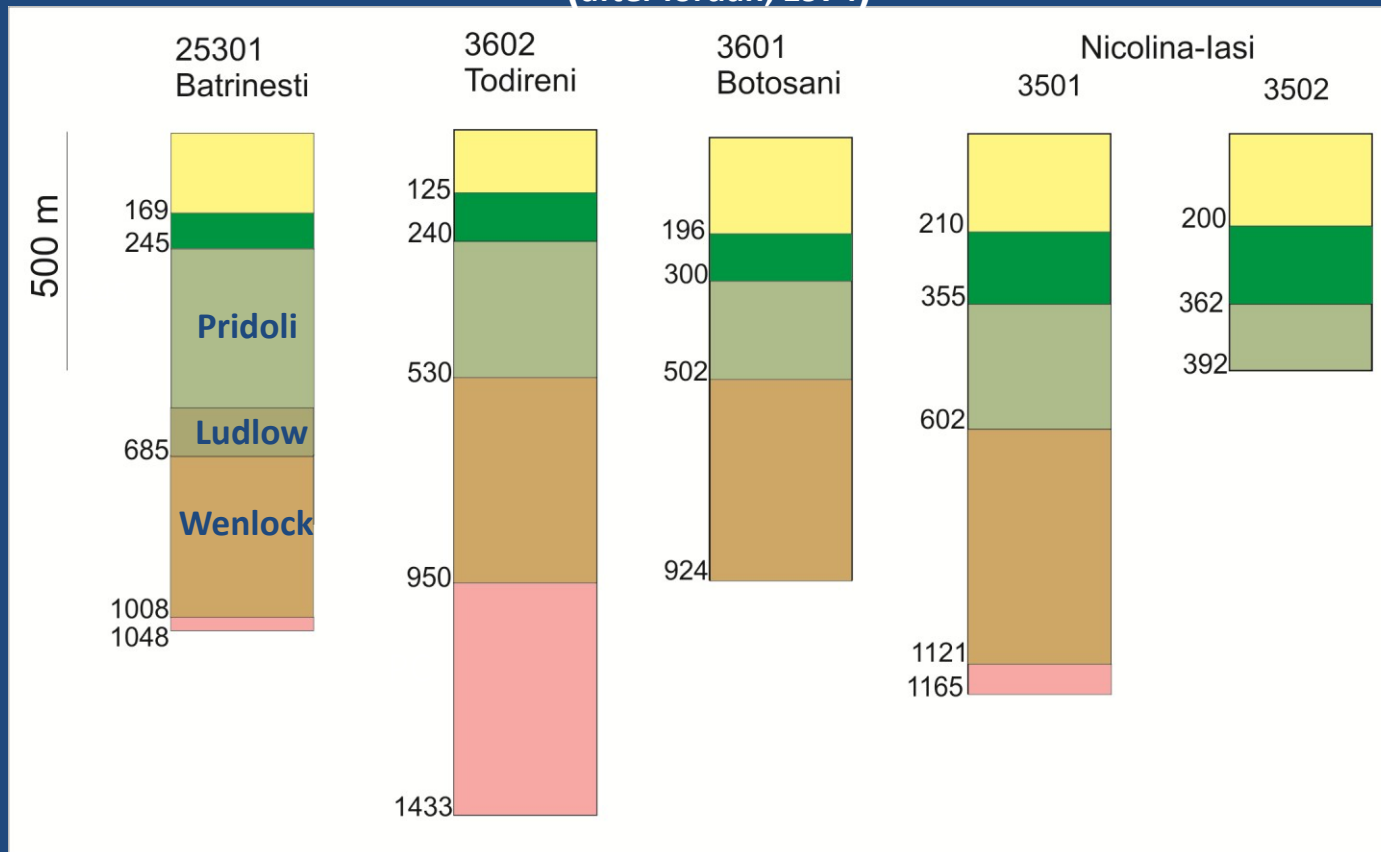
CĂLĂRAȘI BASIN



Wells drilled through Silurian formations of the Moesian Platform
(from Seghedi, 2004)

Wells drilled through Silurian formations of the Moldavian Platform

(after Iordan, 1974)



Sarmatian
Cretaceous

TOC and R_o values from laboratory determinations on core samples from wells drilled through Devonian and Silurian formations in the Moesian Platform

(source: Momea et al.,2001)

<i>Plays</i>	Well Name	Formation/Main Lithology	TOC %	Vitrinite reflectivity Ro [%]
<i>Lom-Bailesti</i>	1111 Garla Mare	Middle Devonian (Giventian) argillites	0.8-3.0	0.35-1.40
		Silurian shales	1.0-1.9	1.40
<i>Calarasi</i>	2881 Calarasi	Middle Devonian (Giventian) argillites	0.73	0.75
		Lower Devonian shales (Lochovian)	0.8-1.0	0.4-0.8
		Silurian (Pridoli-Llandovery) shales	1.5	0.40-1.36

Acomplished:

1. The initial stratigraphic and reservoir evaluation of the Paleozoic shale basins and pays.
2. Established the areal extent of the major shale plays.
3. Definined the prospective area for each shale plays.
4. Estimated the original gas in-place (OGIP).
5. Calculated the technically recoverable **shale gas resources**.

ASSESSMENT PROCEDURE USED

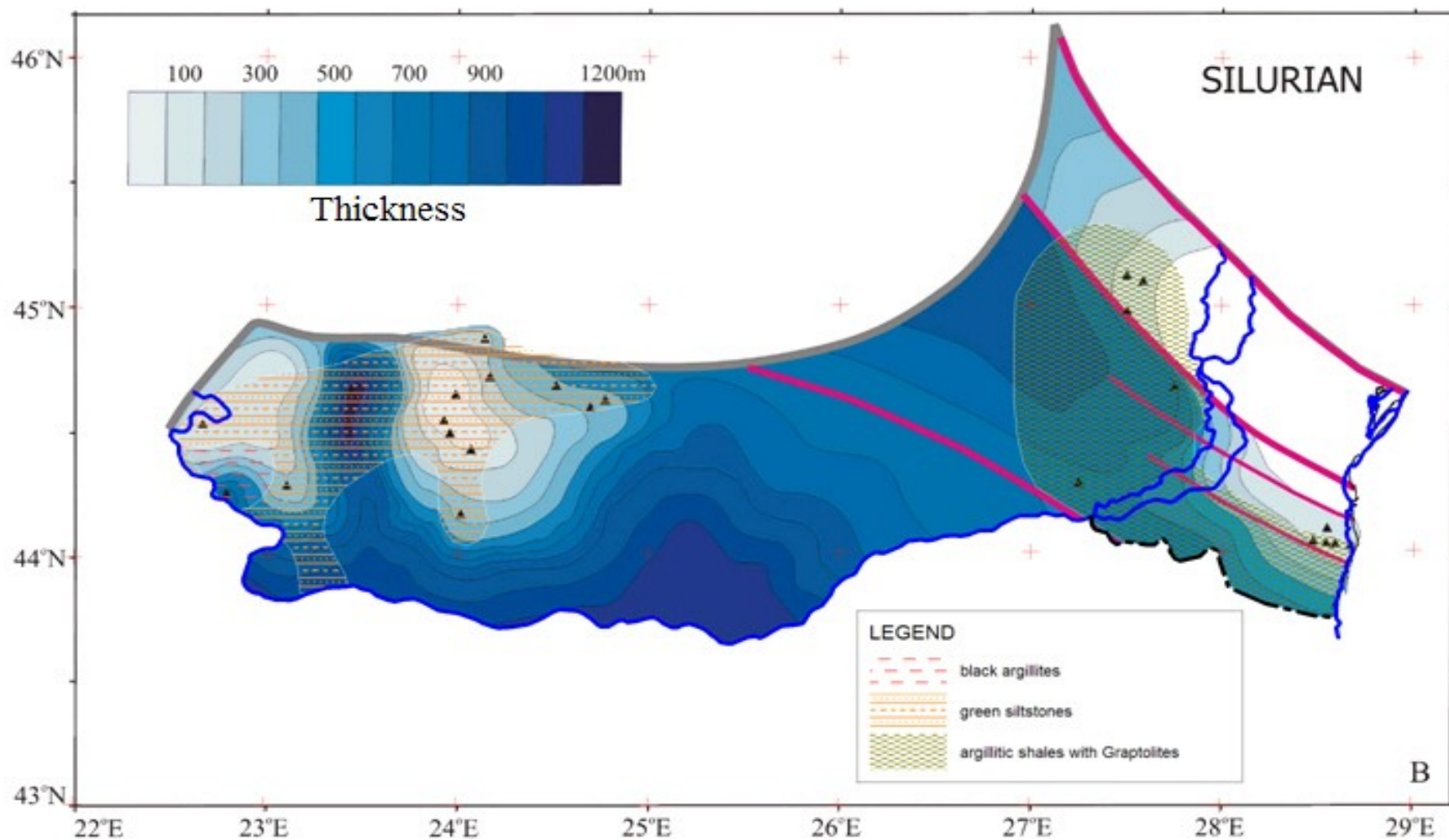
Preliminary geological and reservoir data are assembled for each major shale formation, including the following key items:

- ✓ Depositional environment of shales (mainly marine vs non-marine)
- ✓ Depth (to the top and base of the shale pay)
- ✓ Structure, emphasising major faults
- ✓ Gross shale interval
- ✓ Organically-rich gross and net shale thickness
- ✓ Total organic content (TOC)
- ✓ Thermal maturity (R_o)

These geo-tectonic and reservoir properties were used to provide an overview of the major shale gas plays helping then selecting the shale gas prone intervals worth of further, in-depth assesment

Tools:

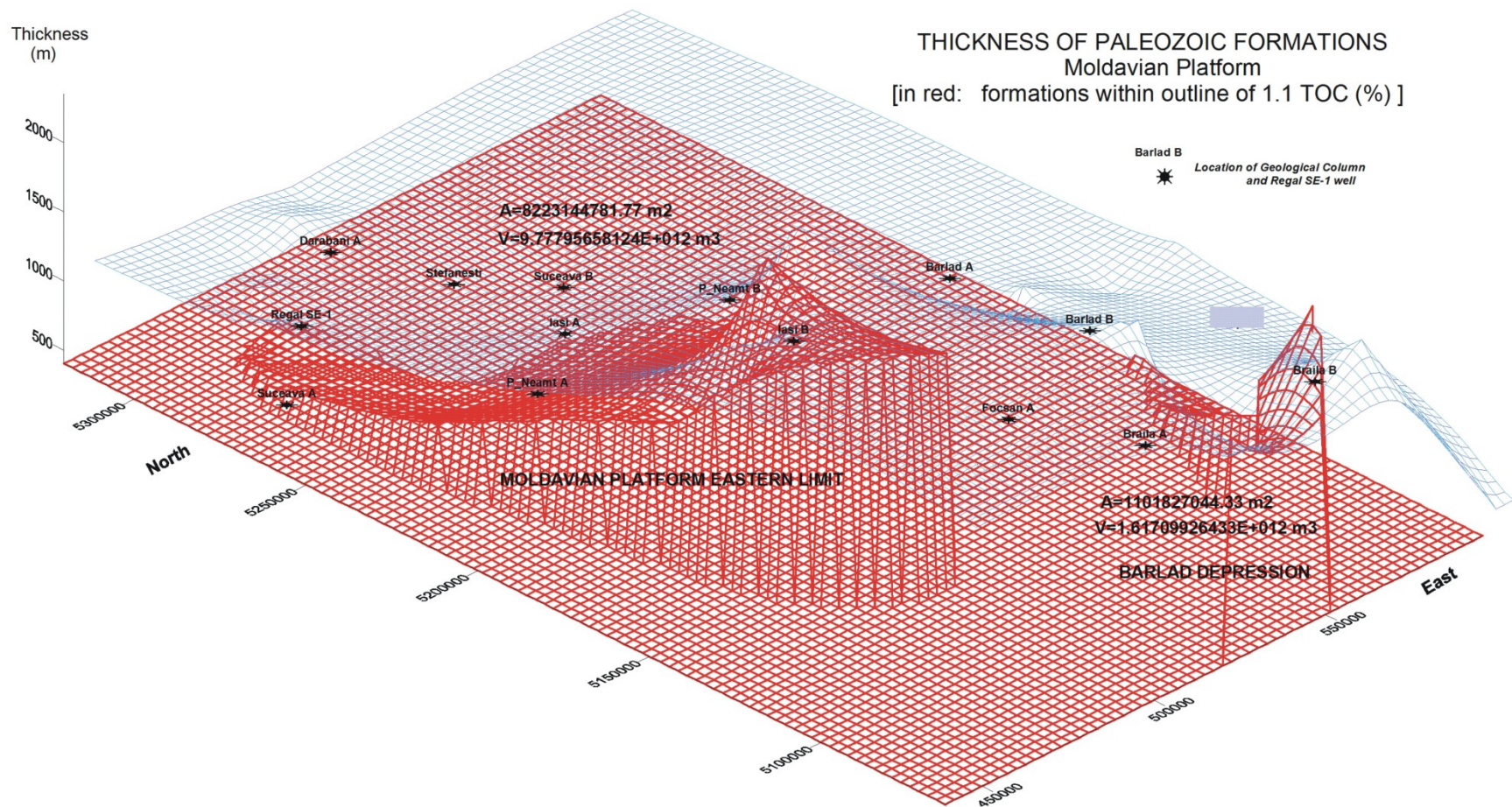
- ❑ Volume calculations were made using the MapInfo v.10 applied on the pre-digitized isopach maps of the Paleozoic formations from Moesia & Moldova.
- ❑ GENEX (Beicip-Franlab) was used for basin analysis.
- ❑ A professional, PHDWin™ software embedding a TRC Consultants L.C. specially designed module for shale gas assessment was used for automatic computation.
(This application calculates original gas in place and estimate recoverable gas resources based on a supplied recovery factor. It has been recommended by numerous workers working in areas where there are number of uncertainties of the reservoir parameters).

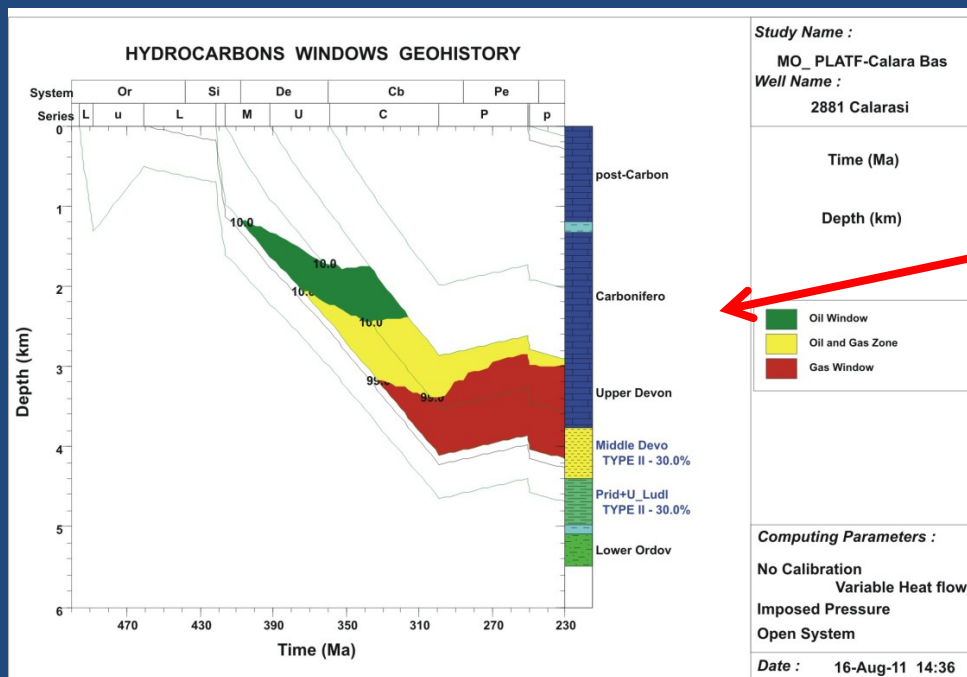


Isopach and facies of the Silurian of the Moesian Platform
(modified from A.Seghedi, 2004)

Thickness
(m)

THICKNESS OF PALEOZOIC FORMATIONS Moldavian Platform [in red: formations within outline of 1.1 TOC (%)]

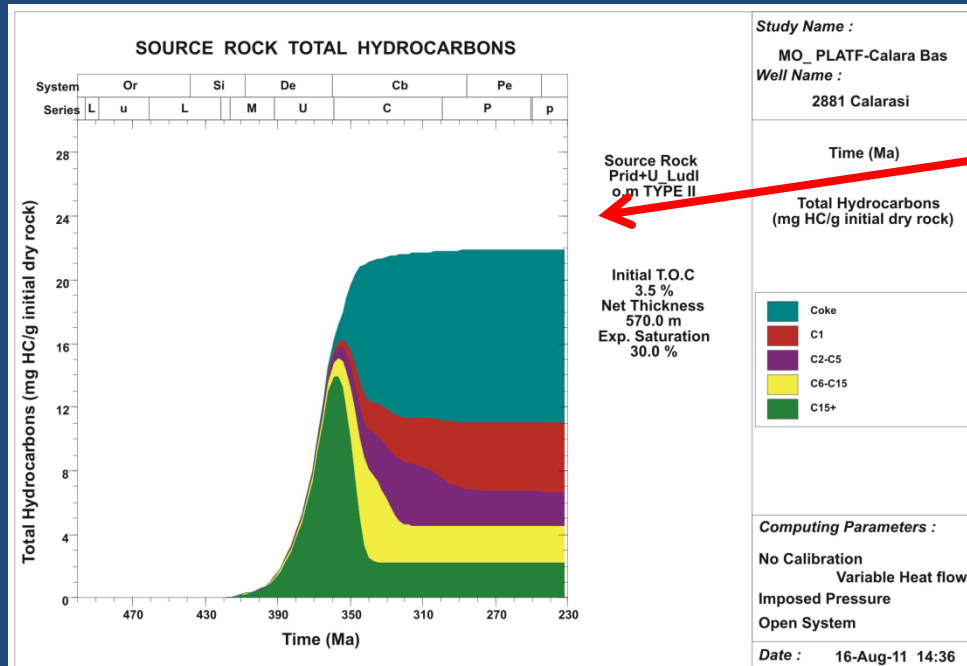




GENEX Software Model:

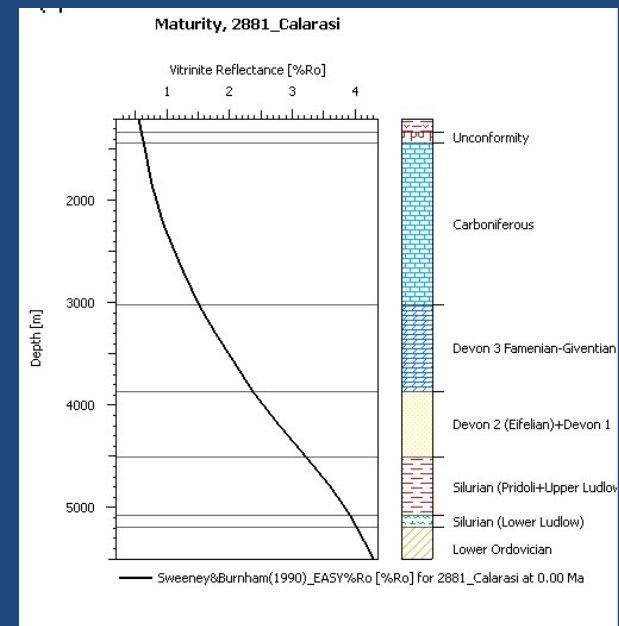
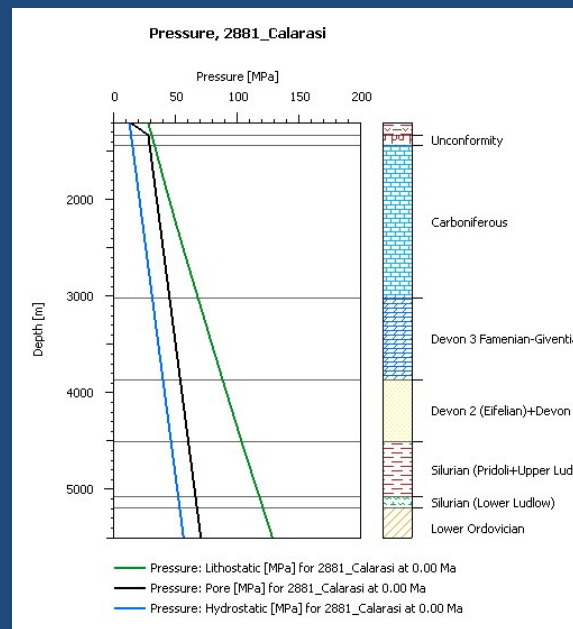
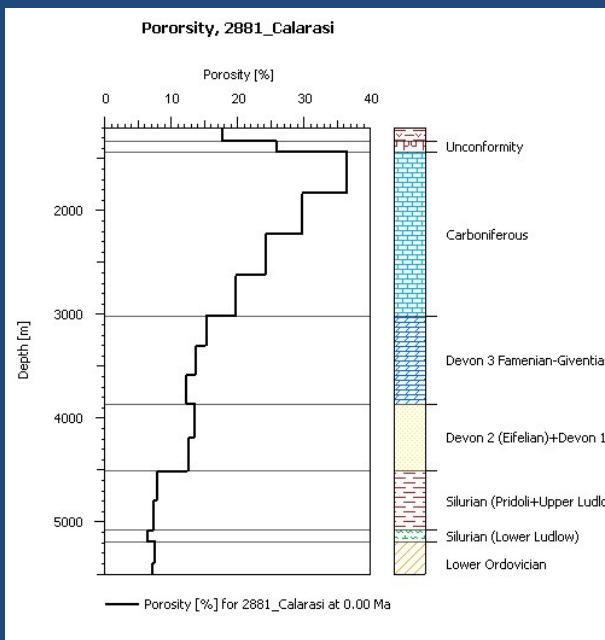
Backstripping

- Temperature Distribution within the Sediments
- Kinetics of Petroleum Generation, Degradation and Expulsion



Source Rock Potential and Total Organic Carbon (TOC)

- Maturity Indicators (Ro%; Hydrogen Index)



The Porosity [%], Pressure [Mpa] and Maturity [%]) were used to provide a first order overview of the geologic characteristics of the Paleozoic formations and to help select the shale gas pays deemed worth of thorough assessment

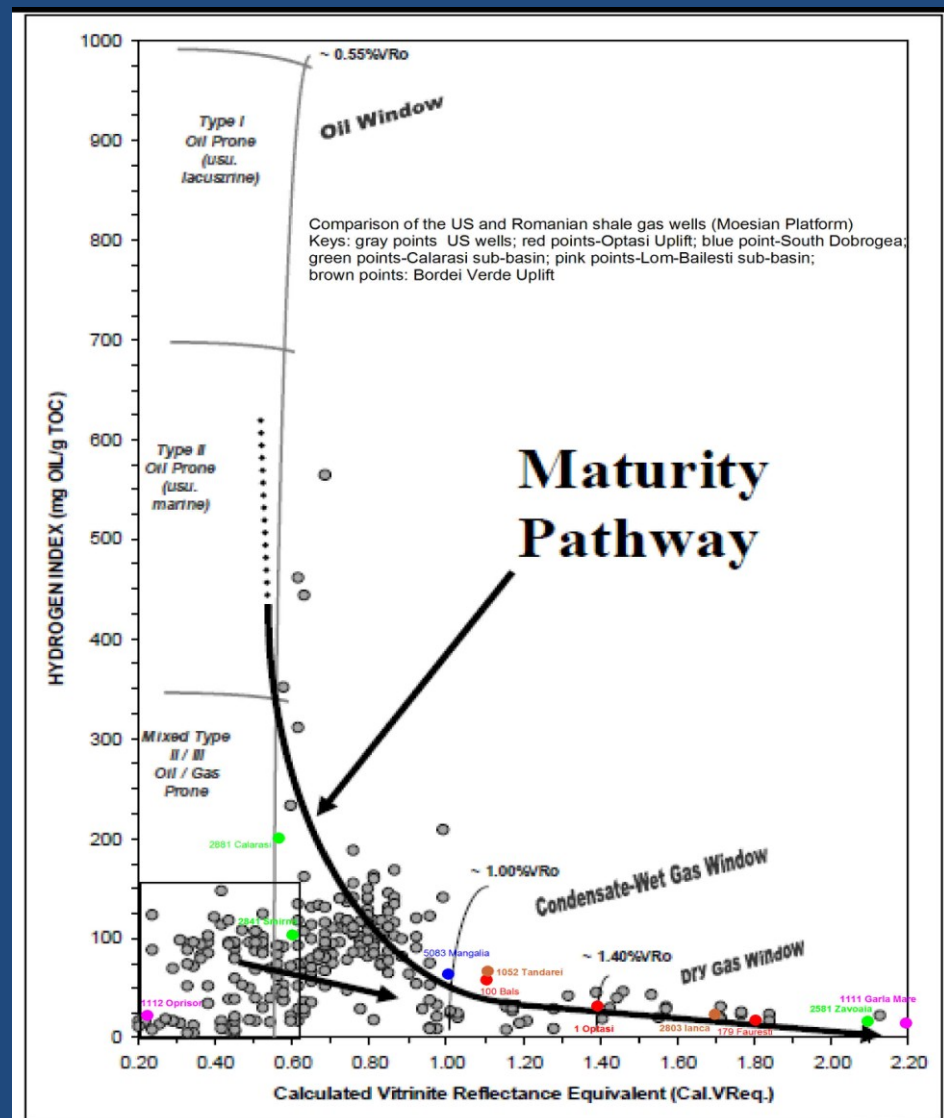
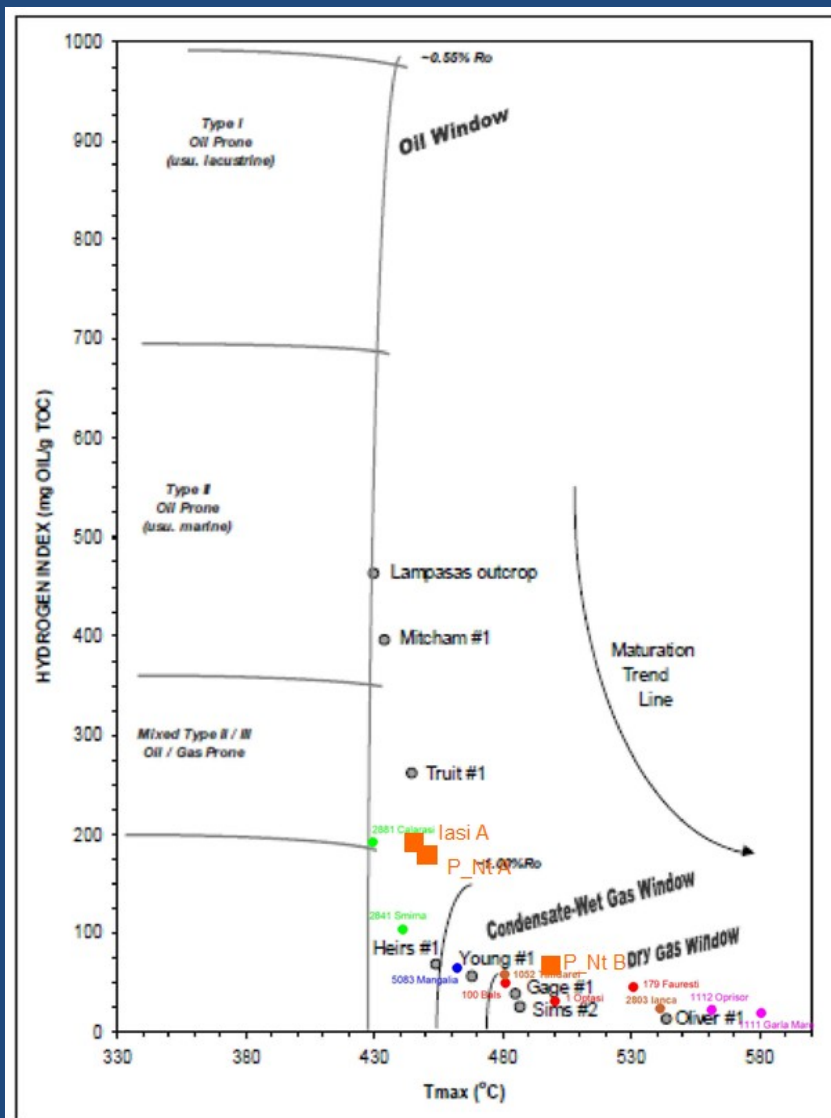
Well modeled: 2881 Calarasi)

Basic data	PLAYS	Western Limit of the Moldavian Platform	Barlád Half Graben (Scythian Ptf.)
	Shale pays	Shales (20-30%); Limestones (30-50%); Sandstones (30%)	Shales (20-30%); Limestones (30-50%); Sandstones (30%)
	Geological age	Silurian-Ordovician	Devonian-Silurian- Ordovician
Physical extent	Prospective Area (acres\sq.km)	2,031,983 \ 8,223	272,267 \ 1,102
	Depth of the top of formations organically rich (ft\m)	1,312-7,709 400-2,350	2,953–12,467 900-3,800
	Average net thickness of formations organically rich (ft\m)	98 30	82 25
Reservoir properties	Pressure (Mpa\psi)	35 3481	30 5366
	Temperature [Rankin]	684	691
	TOC (wt %)	1.1-1.6	1.0-2.4
	Thermal maturity (%Ro)	0.35-1.6	0.58-3.6
	Volume factor Bg	0.0048	0.0033
	z-factor	0.860	0.900

Shale Gas Reservoirs Properties of the Paleozoic formations of the Moldavian Platform

Basic data	PLAYS	Lom-Bailesti	Optasi Uplift (& Alexandria Sb. margin)	Calarasi (& South Dobrogea)
	Shale pays	black shales, argillites	shales, argillites	argillites, shales, clayey schists
	Geological age	Silurian- Lower&Mid Devonian	Silurian- Lower&Mid Devonian	Silurian- Lower&Mid Devonian
Physical extent	Prospective Area (acres)	196,307	2,098,981	2,953,543
	Depth at the top of formations organically rich (ft)	10,100-14,400	6,600 – 8,200	3,000- 12,500
	Average thickness of formations organically rich (ft)	1,132	2,457	1,217
Reservoir properties	Pressure (Mpa)	35	30	28
	Temperature [Rankin]	663	654	636
	TOC (wt %)	0.428-0.966	0.800-1.500	0.728-1.457
	Thermal maturity (%Ro)	0.74-1.90	0.85-1.40	1.00-1.50
	Volume factor Bg	0.0037	0.0043	0.0049
	z-factor	0.9922	1.0000	1.1000

Shale Gas Reservoirs Properties of the Paleozoic formations of the Moesia



Comparison of the U.S. and Romanian (Moesian and Moldavian Platforms) plays

Left: Hydrogen Index vs. Tmax . Right: Calculated Vitrinite Reflectivity Equivalent.

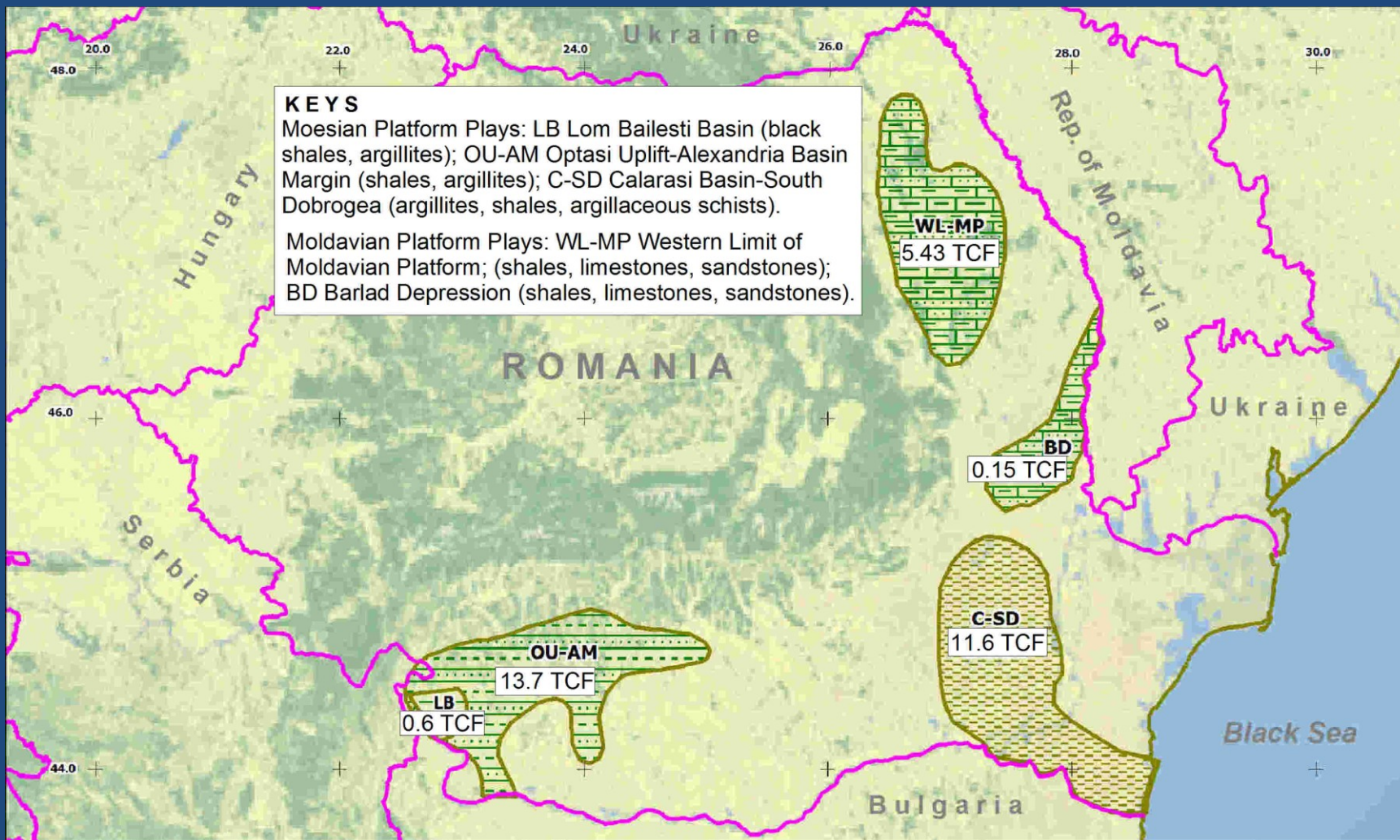
(Keys: gray points = US wells; colored points = Romanian wells)

PLAYS		Western Limit of the Moldavian Platform			Barlad Half Graben (Scithian Pltf.)		
Assessment hypothesis		Pesimistic (P10)	Mean (P50)	Optimistic (P90)	Pesimistic (P10)	Mean (P50)	Optimistic (P90)
Resources	Original gas in place OGIP (Tcf)	271.74			7.30		
	Technically recoverable (Tcf)	2.71	5.43	8.15	0.07	0.15	0.22

Shale Gas Resources Assessment of the Paleozoic pays of the Moldavian Platform

PLAYS		Lom-Bailesti			Optasi Uplift (Alexandria margin)			Calarasi and South Dobrogea		
Assessment hypothesis		Pesimistic	Mean (Swanson's)	Optimistic	Pesimistic	Mean (Swanson's)	Optimistic	Pesimistic	Mean (Swanson's)	Optimistic
Resources	Original gas in place OGIP (Tcf)	29			687			579		
	Technically recoverable (Tcf)	0.3	0.6 (0.58)	0.9	6.9	13.7 (13.73)	20.6	5.8	11.6 (12.44)	17.4

Shale Gas Resources Assessment of the Paleozoic pays of Moesia

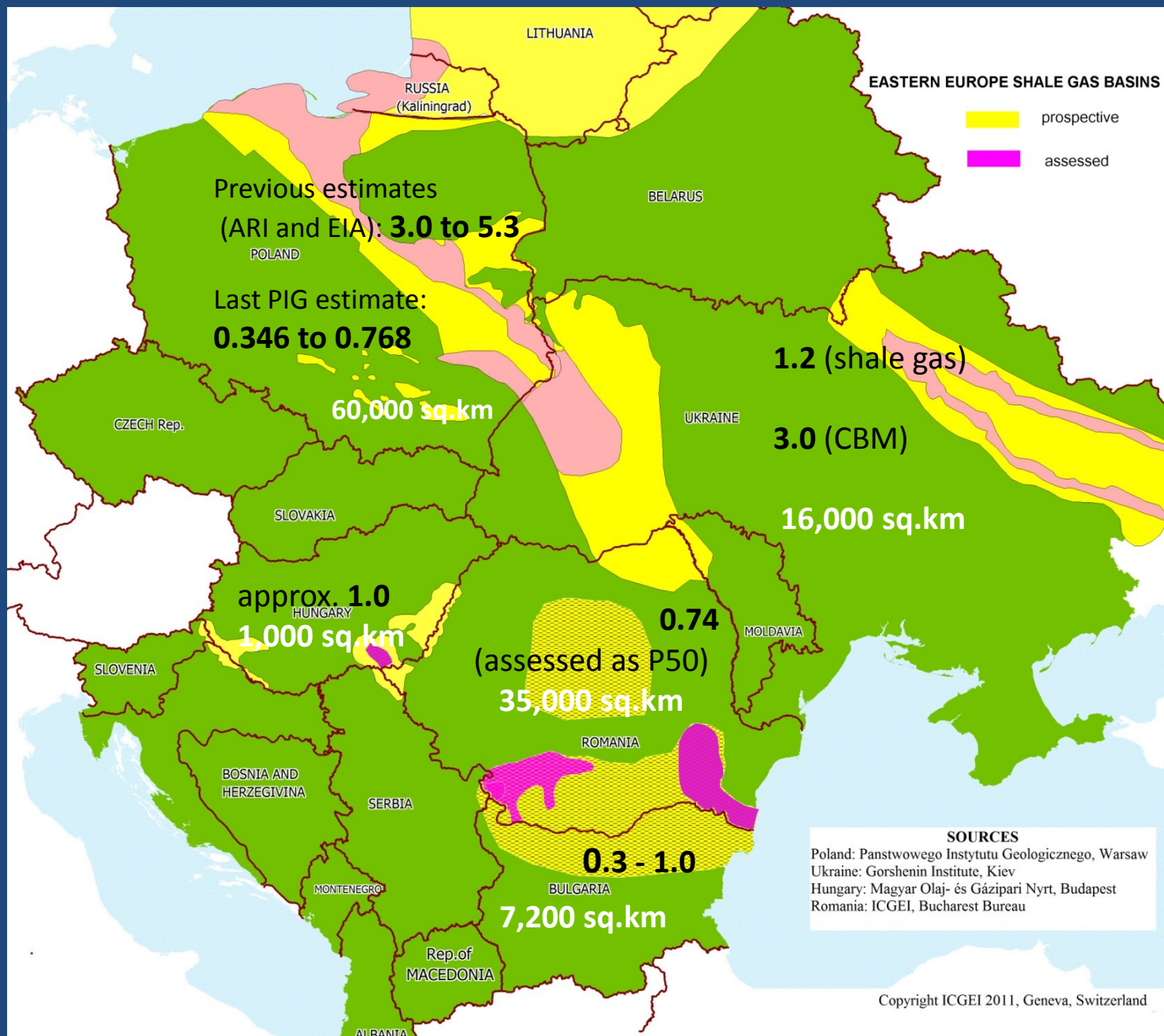


Shale Gas Resources Assessment of the Paleozoic Plays of Romania

Eastern Europe Shale Gas Estimations

Resources:
Risky
Recoverable
in **Tcm**

Aproximate
areas with
Paleozoic
formations
(except
Hungary
that are
Neogene)





**Thank You
for Your
Attention**